

GROUNDWATER DEVELOPMENT IN THE ALTAMAHA RIVER WATERSHED: IMPLICATIONS FOR CONSERVATION OF AQUATIC ECOSYSTEMS

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Abstract. Information is presented on the ecological role of groundwater in the Altamaha River watershed. Although groundwater makes up a substantial portion of baseflow to coastal plain streams, it may have ecological benefit far out of proportion to the quantity of seepage or springflow that reaches the river. Groundwater flows provide reliable sources of cool, fresh water that allow aquatic and estuarine organisms to cope with seasonal temperature and salinity stress and sustain baseflows and nutrient delivery during periods when surface runoff is reduced. It is hypothesized that sustained groundwater flows are a principal source of resiliency to coastal plain aquatic ecosystems that allows populations to survive periodic drought and recover quickly from drought-induced stress. As such it is imperative that protection of ecologically-important groundwater resources be incorporated into plans for aquatic ecosystem conservation and water supply development.

INTRODUCTION

Despite recognition of the hydrologic contribution of groundwater to rivers and streams, the ecological role of groundwater in coastal plain aquatic ecosystems is poorly known and has received relatively little attention. Yet groundwater input to aquatic systems may have ecological benefit far out of proportion to the quantity of seepage or springflow reaching these systems.

In the Altamaha River watershed, cool groundwater discharge from springs, boils and seeps provides thermal refugia during hot summer months for sensitive plant communities, fish and invertebrates. During drought years or unusually dry summers, groundwater input becomes critical to maintaining life support for such species, and some anadromous fishes are known to congregate in large numbers around springs and in spring-fed tributaries during such periods. Fresh groundwater upwelling to tidal creeks in the Altamaha

estuary may also serve as a salinity buffer and a source of minerals in nursery areas for economically important marine species, especially during drought years when freshwater runoff and inflow from coastal rivers is much reduced.

Consequently, overuse of groundwater resources could seriously compromise the viability of some aquatic species and reduce the resilience of aquatic communities to drought. This presentation summarizes insights on the ecological role of groundwater gained from previous studies in the Altamaha basin and similar environments in the Southeast. More focused research is urgently needed on the role of groundwater in coastal plain aquatic ecosystems to better inform discussions on water supply options and to develop strategies for protecting and monitoring ecologically-important groundwater resources.

BACKGROUND

The Floridan Aquifer serves as the major water supply source for the coastal plain region of Georgia, as well as adjoining parts of Florida and South Carolina. Once considered a limitless resource, the Floridan Aquifer today is heavily developed for industrial, municipal, and agricultural use, and portions of the region are straining to cope with problems such as saltwater intrusion, dry wells, declining spring flows and chronically low stream flows brought on by overuse of groundwater. Along with a growing awareness of the need for sustainable limits to pumping from the Floridan has come a renewed interest in alternative water supply sources, including increased development of shallow aquifers, development of upgradient portions of the Floridan Aquifer and use of surface water.

Intensive pumping from the Floridan Aquifer may already have contributed to modest declines in Altamaha River baseflow, reductions in the extent of groundwater upwelling to coastal estuaries, and decreased leakage from the Floridan to overlying

aquifers (GeoSystems Analysis, 2000). Depending on locations and amounts of pumping, projected future increases in the use of Floridan groundwater in the upper coastal plain could significantly reduce river baseflows and discharge from major springs on the Oconee, Ocmulgee, and upper Ochoopee Rivers, which are tributary to the Altamaha. Development of the shallow Miocene and Surficial aquifers has the potential to adversely impact springs and seeps on the lower Altamaha, as well as small blackwater tributaries and isolated wetlands found within the watershed.

ECOLOGICAL SIGNIFICANCE OF GROUNDWATER

Contribution of Groundwater to River Baseflow

Although the Floridan Aquifer underlies most of the coastal plain portion of the Altamaha watershed, its contribution to river baseflow is most significant in the upper coastal plain where the aquifer is shallow and flowing springs are common. Krause and Randolph (1989) estimate that the Floridan contributes approximately 350 cfs to the baseflow of the Ocmulgee River and 115 cfs to the Oconee River, comprising 85-90% of the groundwater-derived baseflow and from 15-30% of the typical summer low flows in these streams. In turn the total Floridan contribution to the baseflow in the Ocmulgee and Oconee Rivers represents nearly 50% of the baseflow to the Altamaha River. The remainder of the Altamaha baseflow is supplied by throughflow of surface water from upstream and groundwater inflow from the Surficial and other shallow aquifers.

During droughts, most of the baseflow in the Altamaha and lower Ocmulgee is derived from groundwater sources. It is also likely that most of the baseflow in low-order blackwater tributaries entering the lower Altamaha is derived from groundwater. Studies of blackwater tributaries to the Savannah River in South Carolina found that as much as 90% of the *total* flows in these streams are from groundwater-derived baseflow (Williams and Pinder, 1990).

Analysis by TNC staff indicate an apparent decline in the annual low flows in the Altamaha River over the past 70 years (TNC, 2000). In part, this decline appears to be the result of regional climate variability that is manifested as an increased frequency of drought since about 1980, but there is also some indication that drought-year low flows have gotten lower since the advent of intensive groundwater use by the pulp and paper industry in the 1950's. Regardless of the source

of the decline in baseflow, the prospect of a warmer climate and more frequent drought in the Southeast elevates the importance of protecting the groundwater flows that sustain the Altamaha and its tributaries during periods when runoff is reduced.

Groundwater and Physiological Refugia

Perhaps even more important than its contribution to baseflow is the fact that groundwater provides reliable sources of cool, fresh water and low levels of dissolved minerals to coastal plain streams and estuaries at times when they are most needed by aquatic organisms. The most significant physiological stress to biota in coastal plain rivers of the Southeast occurs during late spring and summer when seasonal dry spells and cyclic drought result in reduced flows and nutrient delivery, high temperatures, low dissolved oxygen (DO) and increased salinity. In extreme droughts, water temperature, DO and salinity may approach levels that result in mortality of aquatic biota, and even during normal years, many species will be stressed to near their tolerance limits.

Groundwater is perhaps the best buffered portion of the hydrologic cycle due to its relatively long response times to rainfall surplus or deficit. There is evidence that groundwater input to the Altamaha River, its tributaries and its estuary was historically extensive, as it was throughout much of the Southeast and peninsular Florida. Although the area and amount of groundwater input to these systems have been substantially reduced as a result of intensive withdrawals, many economically and ecologically important species rely on sites where groundwater upwelling still occurs during periods of physiological stress (i.e., summer, droughts and severe winters for some species). It is hypothesized that these physiological refugia provide resiliency to aquatic ecosystems that enables more rapid recovery from stress and keeps populations from crashing during droughts. Groundwater features and flows that sustain such refugia are thus a major factor in the maintenance of aquatic biodiversity in the coastal plain.

Sturgeon and anadromous fishes. One of the best examples of dependence on groundwater-sustained refugia in the Altamaha River are the anadromous fishes, especially shortnose (*Acipenser brevirostrum*) and Atlantic sturgeon (*A. oxyrinchus*). These fish have wide geographic ranges along east coast of North America and likely evolved at a time when the climate of the Southeast was much cooler than present. Today they are most numerous in the northern parts of their range, but significant populations occur in several large

southern rivers of which the Altamaha population is arguably the largest and healthiest.

The salinity tolerance of sturgeon is related to water temperature: in the Southeast, juveniles and adults occupy oligohaline to fresh tidal reaches of estuaries on a year-round basis, but are not found in waters with greater than about 2.5 ppt salinity during summer months when water temperature is above 20° C. (Rogers and Weber, 1995). Shortnose sturgeon are thought to be intolerant of water temperatures greater than 28°C. regardless of salinity (Rogers, personal communication). Such elevated temperature and salinity conditions occur with regularity during summer in the tidal freshwater portions of the Altamaha.

Locations where springs or groundwater-fed tributaries produce zones of cool, fresh water in the river may serve as physiological refugia for sturgeon, during spawning migration and during hot, dry periods in the summer. Several locations in the Altamaha delta, notably at Ebenezer Bend on the south Altamaha and a similar site on the Champney River, have been identified as critical summer refugia for both Atlantic and shortnose sturgeon. Previous research indicates that freshwater springs at these sites likely produce zones of cooler, lower salinity water that enables sturgeon to survive (albeit in a state of reduced activity) the otherwise harsh conditions that prevail in the river during the summer (Flournoy *et al*, 1992).

Such refugia are perhaps most important to the shortnose sturgeon, which unlike the Atlantic sturgeon, is confined exclusively to habitat within the river, and to the juveniles of both species, which typically have lower tolerance than adults for extremes of temperature and salinity. On the Altamaha, nearly the entire population of shortnose sturgeon and a large number of Atlantic sturgeon aggregate at the Ebenezer and Champney sites each summer and disperse when temperatures cool and flows increase in the fall. It is not known whether these sites have always served as the main refugia for sturgeon on the Altamaha or whether they are simply the only remaining locations where artesian springflow still occurs now as it historically did throughout the estuary. However, it is clear that reduction in springflow at these sites could have profound implications for the survival of the Altamaha shortnose sturgeon population and on recruitment of juvenile Atlantic sturgeon that oversummer here.

The summer aggregation of gulf sturgeon and striped bass at springs in the Suwanee, Appalachicola and Flint Rivers (Mason and Clugston, 1993; Wooley and Crateau, 1994) suggests that anadromous fishes on

the Altamaha may be likewise using such features as thermal refugia. Many adult Atlantic sturgeon migrate to waters north of Cape Hatteras during summer, but some, perhaps late spawners stranded by rising water temperature downstream, have been observed overwintering near boils and springs on the lower Oconee and Ocmulgee Rivers, (Rogers, personal communication). The scattering of place names such as "Sturgeon Creek" and "sturgeon hole" near spring heads and in spring-fed tributaries throughout this region give historical credence to these modern-day observations. Known spawning and nursery sites for American (*Alosa sapidissima*) and hickory shad (*A. mediocris*) and striped bass (*Morone saxatilis*) in the Altamaha basin are likewise clustered in portions of the upper coastal plain where springs and spring-fed streams are prevalent.

Other Groundwater-Dependent Species. In addition to providing critical habitat for anadromous fishes, groundwater-fed streams and spring heads are the near-exclusive habitat of certain other rare coastal plain fish species such as redeye chub (*Notropis harperi*) and Christmas darter (*Etheostoma hopkinsi*). These species occur in small spring-fed tributaries of the Oconee and Ocmulgee Rivers where they presumably find suitable temperature and water chemistry (Lee *et al*, 1980). Many other fish that inhabit intermittent streams will move to spring heads and pools during the summer to avoid desiccation (Mammoliti, 1998).

Like many fish species, endemic mussels on the Altamaha River are sensitive to high water temperatures and often experience increased mortality from exposure and elevated temperatures during droughts. However, the most abundant and persistent mussel populations on the Altamaha occur in sloughs behind sandbars where cool groundwater seeps from adjacent undeveloped uplands and floodplain terraces. Surveys during the drought summer of 2000 suggest that seepage-cooled mussel beds in Appling and Tattnall Counties remained healthy despite lowered water levels and loss of connection with the river channel.

Groundwater also supports distinctive bluff and seepage slope communities in the Altamaha floodplain, where seepage creates a cool, moist micro-climate conducive to growth of plants more commonly found much farther north in the Piedmont (R. Hicks, The Timber Co., personal communication). Similar communities also historically occurred on the upland edges of coastal marshes in the Altamaha delta and

were presumably sustained by seepage from adjacent upland maritime forests. Forested seeps provide the exclusive habitat for Say's spiketail (*Cordulegaster sayi*), a rare species of dragonfly endemic to the south Atlantic coastal plain and found in the Altamaha basin at the base of bluffs in upper Wayne County and along the Ochoopee River. Groundwater seepage from the base of riverine bluffs also provides important basking and "drinking" habitat for many species of butterfly.

Importance of groundwater to the Altamaha estuary. Although estuaries are often thought of as saltwater bodies, the importance of freshwater inflows to these systems is well documented in the scientific literature. It is known that inflow of fresh surface water and associated nutrients from upstream is critical to the survival of many estuarine species and that reductions in freshwater flow can result in adverse impacts to the estuarine ecosystem. However, the role of fresh groundwater inflow to estuaries is poorly understood, despite evidence that groundwater upwelling was once plentiful and widespread in the coastal zone.

Studies in north Florida estimate that diffuse groundwater seepage to estuaries is comparable to the flow of a small river or "first-magnitude spring" in the amount of fresh water delivered on an annual basis (Cable *et al*, 1997). In salt marsh estuaries that are poorly connected with inland rivers and in riverine estuaries during periods of low flow, groundwater seepage and upwelling become the most ecologically-important sources of fresh water. As such, groundwater inflow to the Altamaha estuary may be critical to the long-term viability of marsh plants, marine mammals and economically important shellfish.

In a study of salt marshes in Virginia, Nuttle and Harvey (1995) determined that upward seepage of fresh groundwater contributes up to 65% of ET replacement during the growing season and is responsible for net advection of salts out of wetland soils during the winter when ET demands are minimal. Steady seepage of groundwater may be crucial in maintaining the salt balance in pore water necessary for marsh plant survival, especially during droughts, and in preventing long-term salt accumulation in wetland soils. Several researchers have indicated that groundwater seepage to estuaries is an important source of new nutrients for plants and invertebrates during otherwise nutrient-starved dry periods, equivalent to the nutrient delivery of a "small, local river" (Rutkowski *et al*, 1999; Kitheka *et al*, 1999).

Although inhabiting marine waters as adults, juvenile shrimp and blue crab require more moderate

salinity for optimal growth and production (Whitaker, 2000; Guerin and Stickle, 1992). Brown (*Penaeus aztecus*) and white shrimp (*P. setiferus*), the main economically important shrimp species in Georgia, need salinities from 7.5-15 ppt in estuarine nursery grounds (Whitaker, 2000). During most years fresh water delivery from the Altamaha River maintains salinity of the estuary well within these ranges. However, during drought years such as 1999 and 2000 when flows from the river are minimal, salinity may rise to as high as 20-25 ppt in portions of the estuary most often utilized by juvenile shrimp, except in tidal creeks that still receive freshwater inputs from groundwater. Historical accounts from the Georgia coast suggest that groundwater input to tidal creeks was formerly more common than it is today and that these areas served as salinity and thermal refugia for shrimp. In the absence of adequate groundwater upwelling to support these refugia, shrimp harvest may be much reduced during drought years as a result of decreased recruitment of juveniles and delayed movement from nursery grounds to offshore waters (Whitaker, 2000).

High temperatures and salinities associated with drought are also detrimental to populations of the Atlantic blue crab (*Callinectes sapidus*) because such conditions favor infections by the dinoflagellate parasite *Hematodinium*. Lee (2000) found that during the drought summers of 1999 and 2000 blue crabs virtually disappeared from Wassaw Sound, a salt marsh estuary that receives little or no freshwater flows, as a result of *Hematodinium* infection, while crabs in nearby Ossabaw Sound, which receives freshwater flows from the Ogeechee River, remained relatively uninfected and harvests remained stable. However, the research discovered at least one small creek near Wassaw Sound that continued to have crabs during the summer of 2000. This creek appears to have freshwater input from an "underground spring" as evidenced by lower sediment temperature and salinity compared with nearby creeks (Lee, 2000).

The West Indian manatee (*Trichechus manatus*), which inhabits the Altamaha estuary during summer, cannot survive without access to fresh water, making groundwater inflow to the estuary critical for this endangered mammal during dry summers when the saltwater interface moves far upstream. Farther south along the Florida coast, constant-temperature flows from Floridan aquifer springs provide a reliable source of relatively warm water in winter that enable manatees to survive sudden cold snaps.

AQUATIC CONSERVATION STRATEGIES

Future groundwater development in the Altamaha watershed combined with the prospect of more frequent drought will pose significant challenges to the conservation of aquatic ecosystems in the region. Research is needed to shed additional light on relationships between groundwater flows, physiological refugia and maintenance of aquatic biodiversity. Field studies and hydrologic modeling will be needed to identify groundwater sources and features that provide critical life support functions for aquatic species or which add resiliency to aquatic ecosystems.

Protecting instream springs and physiological refugia as well as fish access to such features may require a different set of conservation strategies than are normally used in land-based conservation efforts, including hydrologic restoration, water use and flowage easements and creation of aquatic preserves. Protection of ecologically-important groundwater resources may also require land-based conservation action for features outside the river channel, including upland recharge areas and "ground-watersheds" for springs and seeps, bluff forests and headwater wetlands.

Strategies can be developed for encouraging sustainable water use that is compatible with conservation goals. Such strategies include: working with water users to develop alternative water supplies or locating wells in areas that will minimize impacts to sensitive species, providing incentives for using less water in irrigation and industrial practices or for reducing use during times of the year when groundwater is most critical to the aquatic resource.

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